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# LHeC Final Focus System


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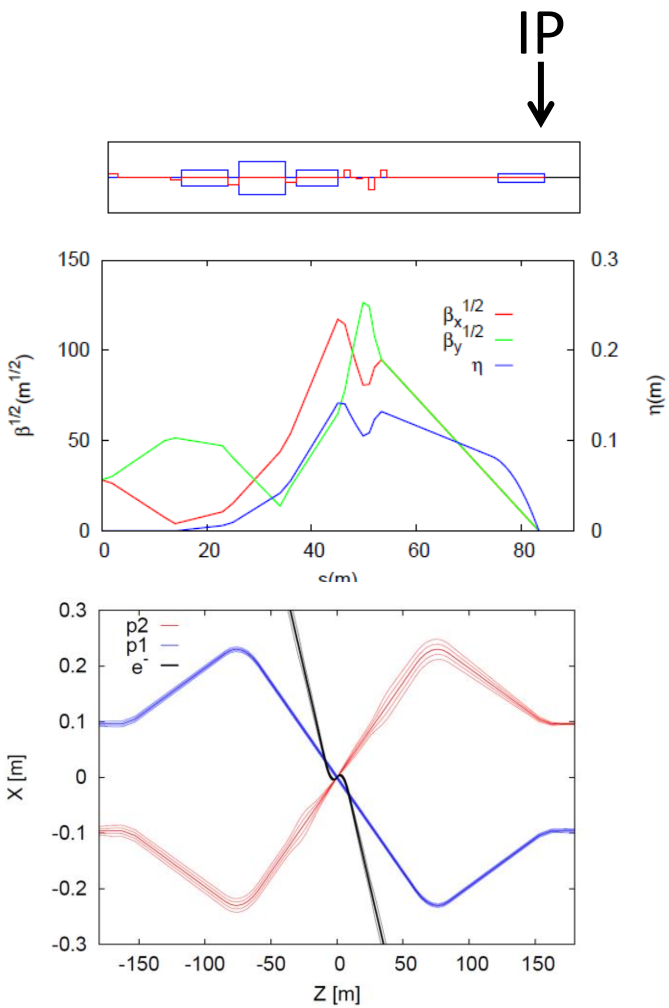
Thanks to: H. Garcia, R. Tomas, F. Zimmermann

# Contents

- Round optics. $e^-$ FFS optics I: triplet
- Flat optics:
  - $e^-$ FFS optics II: Doublet, local chromatic correction
  - $e^-$ FFS optics III: Doublet, traditional chromatic correction

Introduced in the talk **Interaction Region** by R. Tomas (this workshop)

# e⁻ FFS optics I: triplet



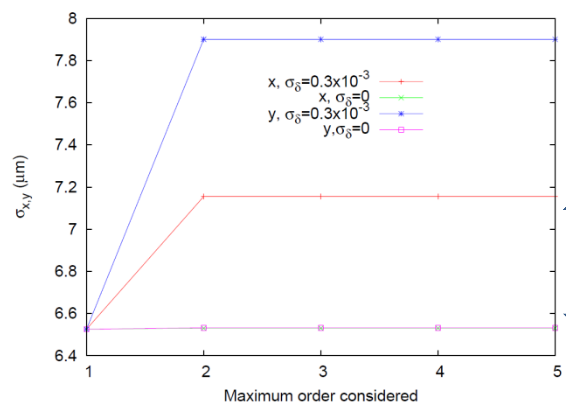

$\beta^*_{x,y} = 0.1$ m.

No chromatic correction

Bending magnets to compensate the dispersion created by the last dipole

**Beam size by order computed with MAPCLASS**

*R. Tomas, CERN AB-Note-2006-017 (ABP) (2006).*




Chromatic aberration

# Flat beam optics

**Chromatic correction**

- 4 Sextupoles to correct chromaticity in pairs
  1st pair: correction in X. $\beta_x >> \beta_y$
  2nd pair: correction in Y. $\beta_x << \beta_y$

  Separation of β-functions

$\beta^*_{x,y} = 0.1$ m. → $\beta^*_x = 0.2$ m. / $\beta^*_y = 0.05$ m.

Different β* to separate β-functions

- Each of the sextupoles of the pair must be spaced $\Delta\mu_{x,y} = \pi$
- 2 arrangements
  - Traditional, dedicated section
  - Compact, Local chromatic correction

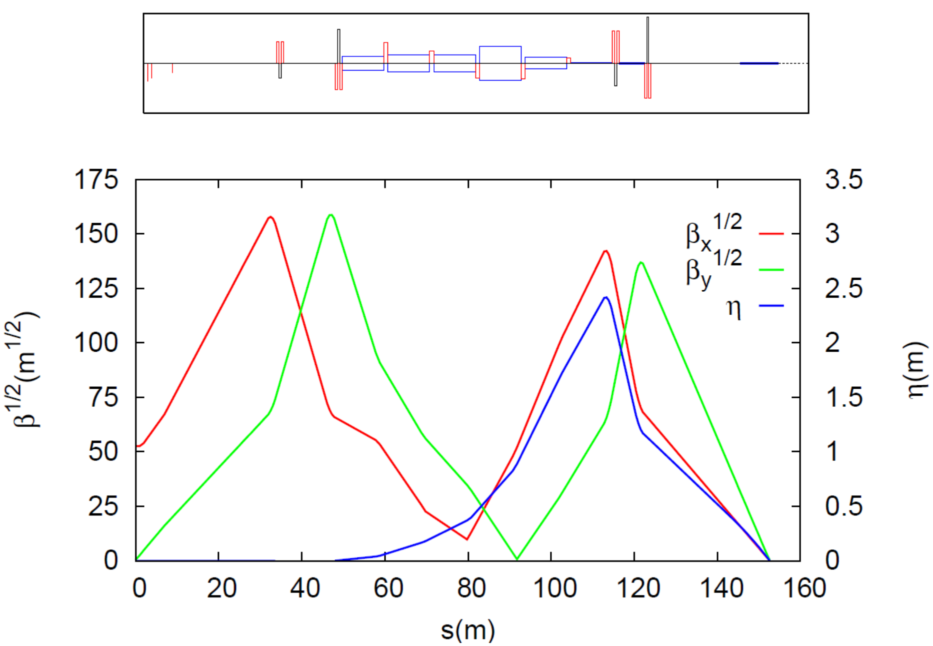
  *P. Raimondi and A. Seryi, Phys. Rev. Lett. 86, 3779 (2001).*

# e⁻ FFS optics II: local chrom. corr.

Dipole
Quadrupole
Sextupole

| $\beta^*_x$ =0.2 m. |
| --- |
| $\beta^*_y$ = 0.05 m. |

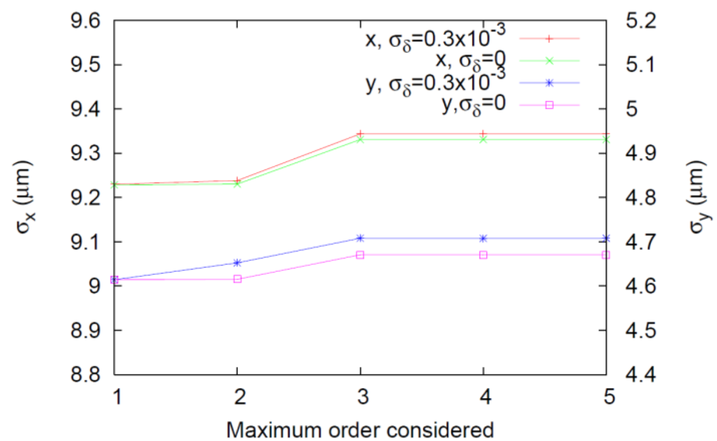
IP



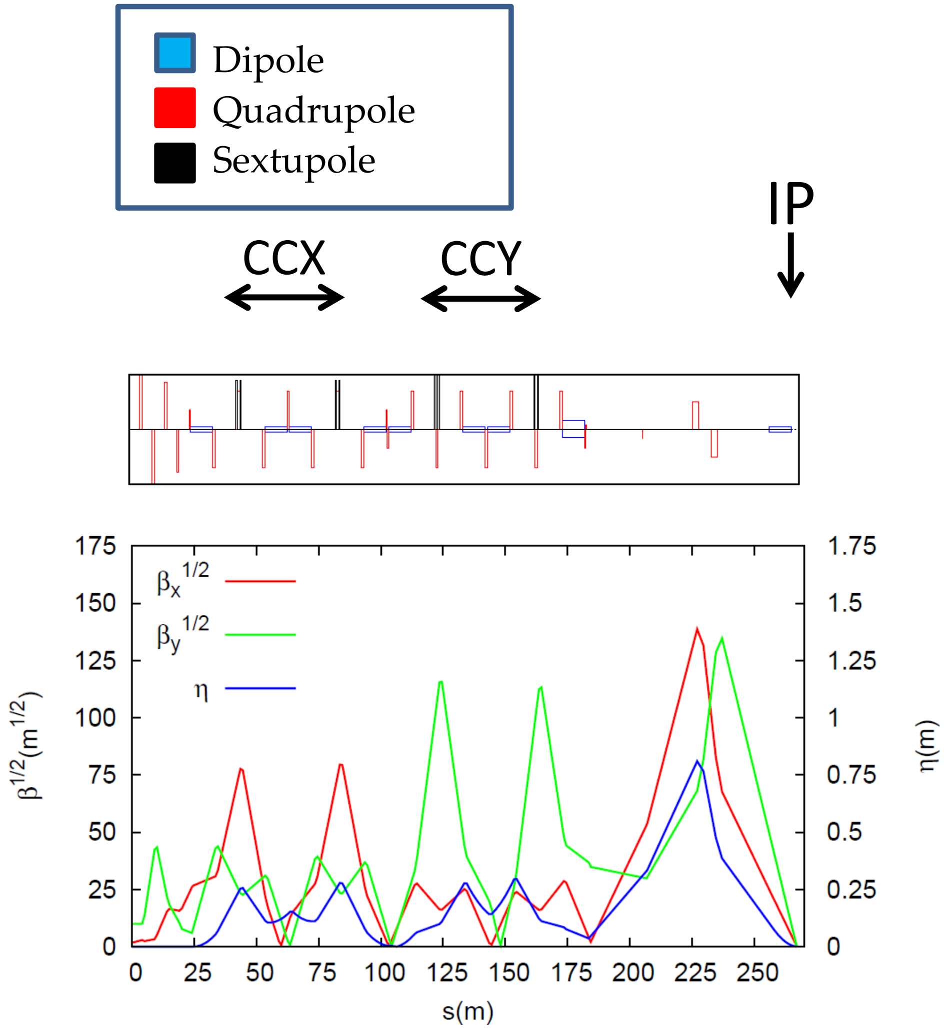

Length : 150 m

**SR power** of 83 kW

**Beam size by order**



# e⁻ FFS optics III: Traditional



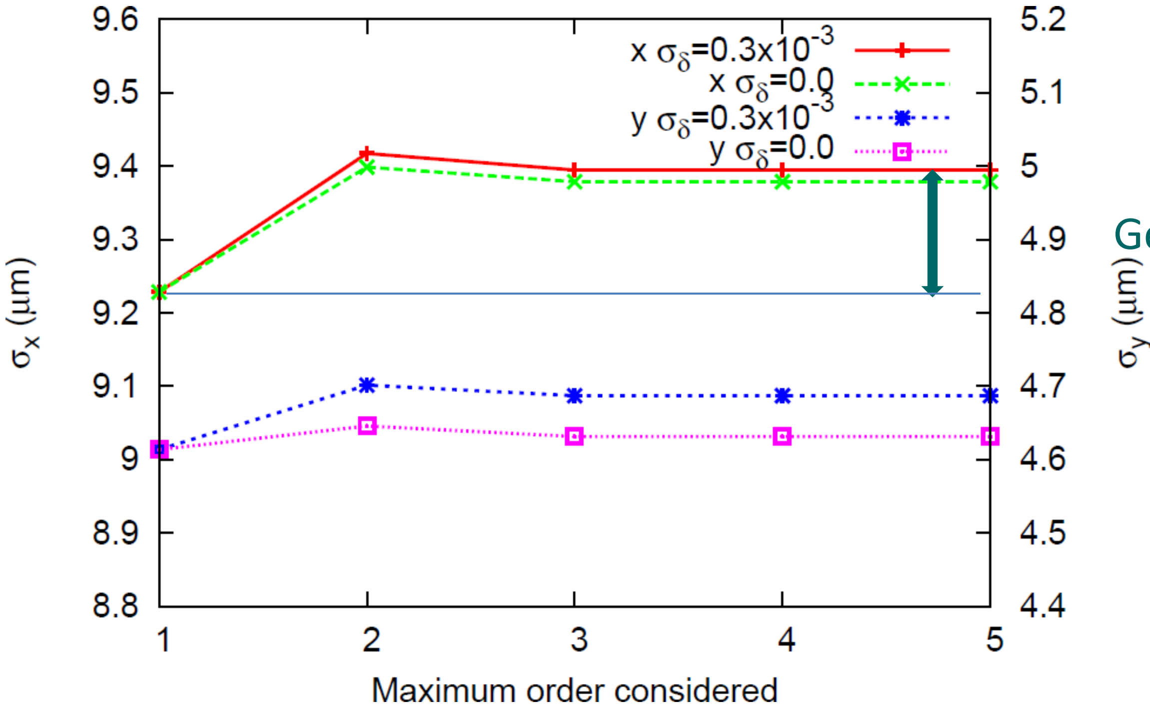

| |
|---|
| $\beta^*_x = 0.2$ m. |
| $\beta^*_y = 0.05$ m. |

Length : 267 m (too long)
Modular construction:
Chromaticity compensated two dedicated sections.
Separated optics with strictly defined functions that makes the system relatively simple to design.
Chromaticity is not locally corrected.

**SR power** of 39 kW

# $e^-$ FFS optics III: Traditional

**Beam size by order**

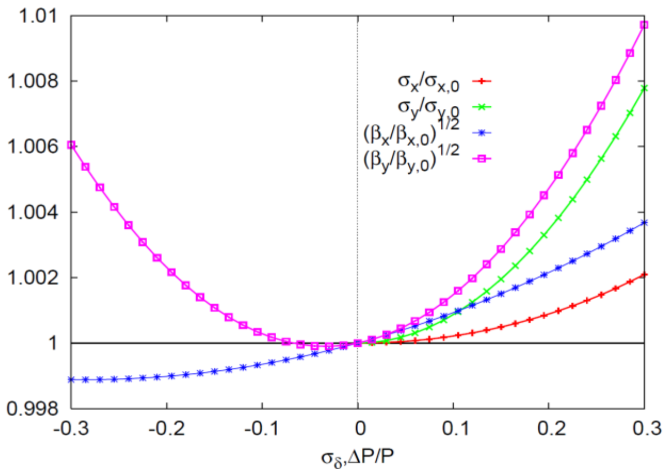



Geometric aberration

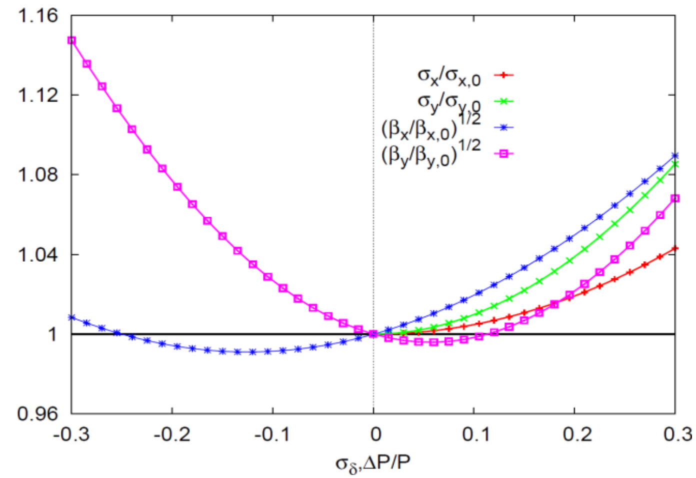
# Flat beams comparative

## Bandwidth

e$^-$ FFS optics II




e$^-$ FFS optics III: Traditional




Much wider bandwidth for the local chromatic option →
more stable for energy variations

# Flat beams comparative

Momentum spread $\sigma_\delta = 0.3 \times 10^{-3}$ without synchrotron radiation evaluated by tracking with PLACET

| | $\sigma_x$ [μm] | $\sigma_y$ [μm] |
|---|---|---|
| Local | 9.34 | 4.69 |
| Traditional | 9.75 | 4.97 |

Synchrotron radiation effects due to **emittance dilution** in the horizontal plane.

| | $\sigma_y$ [μm] w/o SR | $\sigma_x$ [μm] W SR | $\sigma_x$ [μm] Expected* |
|---|---|---|---|
| Local | 9.41 | 22.24 | 22.33 |
| traditional | 10.15 | 12.84 | 13.63 |

* $\Delta(\sigma_x{}^*/\beta_x{}^*)=4.13\text{x}10^{-11} m^2 GeV^{-5} E^5 I$

$$I = \int_0^L \frac{H(s)}{|\rho(s)^3|} \cos^2 \phi(s) ds$$

$$H = \frac{D^2{}_x + (D'{}_x\beta_x + D_x\alpha_x)^2}{\beta_x}$$

*M. Sands, SLAC/AP-047 (1985).*

# Magnet comparison

| | triplet | | | doublet - local | | | doublet - traditional | | |
|---|---|---|---|---|---|---|---|---|---|
| Name | Gradient [T/m] | Length [m] | Radius [mm] | Gradient [T/m] | Length [m] | Radius [mm] | Gradient [T/m] | Length [m] | Radius [mm] |
| Q1 | 19.7 | 1.34 | 20 | −19.1 | 1.1 | 36 | -20.54 | 2.5 | 36 |
| Q2 | −38.8 | 1.18 | 32 | 17.7 | 1.1 | 37 | 20.31 | 2.5 | 35 |
| Q3 | −3.46 | 1.18 | 20 | −14.7 | 1.1 | 41 | -6.59 | 0.3 | 17 |
| Q4 | 22.3 | 1.34 | 22 | 11.8 | 1.1 | 41 | 2.85 | 0.3 | 13 |

# Conclusions

- A chromatic correction needs high dispersion regions in the sextupoles that introduce SR and emittance growth
- Restriction in length
- Restriction in L*
- Three different solutions have been studied and presented

# Conclusions

## Three different e- FFS optics

| | Main advantages | Main disadvantages | Future |
|---|---|---|---|
| optics I: Triplet | Simple and short | Chromaticity not corrected | |
| optics II: Doublet, local chromatic correction | Short | Large emittance growth from synchrotron radiation | H-function optimization |
| optics III: Doublet, traditional modular chromatic correction | Chromaticity corrected with low emittance growth | Too Long? | If there is enough space |

# References


- J.L.  Abelleira, N. Bernard, S. Russenschuck, R. Tomas, F. Zimmermann; Proc. IPAC’11 San Sebastian, p. 2796.
- J.L. Abelleira, H. Garcia, R. Tomas, F. Zimmermann; IPAC’12 New Orleans

*Thank you for your attention*